

**Abstract of the Disclosure**

A composite  $\alpha$ -Ta/graded tantalum nitride/TaN barrier layer is formed in Cu interconnects with a controlled surface roughness for improved adhesion, electromigration resistance and reliability. Embodiments include lining a damascene opening, such as a dual damascene opening in a low-k interlayer dielectric, with an initial layer of TaN, forming a graded tantalum nitride layer on the initial TaN layer and then forming an  $\alpha$ -Ta layer on the graded TaN layer, the composite barrier layer having an average surface roughness (Ra) of about 25Å to about 50Å. Embodiments further include controlling the surface roughness of the composite barrier layer by varying the N<sub>2</sub> flow rate and/or ratio of the thickness of the combined  $\alpha$ -Ta and graded tantalum nitride layers to the thickness of the initial TaN layer.